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GEOLOGICAL SURVEY CIRCULAR 609

Mercury in Soil Gas and Air— A Potential Tool in Mineral Exploration

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GEOLOGICAL SURVEY CIRCULAR 609

Washington 1969

United States Department of the Interior
WALTER J. HICKEL, *Secretary*

Geological Survey
William T. Pecora, *Director*

First printing 1969
Second printing 1969
Third printing 1970

Free on application to the U.S. Geological Survey, Washington, D.C. 20242

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Abstract

The mercury content in soil gas and in the atmosphere was measured in several mining districts to test the possibility that the mercury content in the atmosphere is higher over ore deposits than over barren ground. At Cortez, Nev., the distribution of anomalous amounts of mercury in the air collected at ground level (soil gas) correlates well with the distribution of gold-bearing rocks that are covered by as much as 100 feet of gravel. The mercury content in the atmosphere collected at an altitude of 200 feet by an aircraft was 20 times background over a mercury deposit and 10 times background over two porphyry copper deposits. Measurement of mercury in soil gas and air may prove to be a valuable exploration tool.

INTRODUCTION

Mercury anomalies have been found in rocks and soils of many base- and precious-metal ore deposits (Gott and McCarthy, 1966; Gott and others, 1967; Hawkes and Williston, 1962; Ozerova, 1962), and their successful use as a pathfinder has been demonstrated (Erickson and others, 1966). Sergeev (1961) has demonstrated a correlation between the concentration of mercury in soil and the soil gases that overlie mercury deposits. The high vapor pressure of mercury suggests that mercury vapor would be released from a source of mercury at depth. The diurnal variation in atmospheric pressure and temperature would cause pulsations in the atmosphere and soil gas and would result in the exhalation of mercury through the earth's "breathing process."

In the preliminary experiments described here, the mercury in soil gas and in the atmosphere was collected by amalgamation on gold or silver foil and was subsequently released and measured by an atomic-absorption instrument (Vaughn, 1967). A small aircraft was used to sample air at altitudes of 100 to 1,000 feet.

These experiments were undertaken as part of the Heavy Metals program of the U.S. Geological Survey in an effort to develop new methods of geochemical exploration. The data collected to date, though few, are encouraging. Additional experiments are underway to evaluate this technique further.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the cooperation of Mr. Lee Stoiser and Mr. Hatfield Goudey, of the American Exploration & Mining Co., for supplying maps and information on depth of overburden in the Cortez area, and Mr. W. C. Lawson, of the Phelps-Dodge Corp., and Mr. J. H. Courtright, of the American Smelting and Refining Co., for their help in arranging low-level flying over the copper deposits at Ajo and Silver Bell.

APPARATUS AND TECHNIQUE FOR MEASURING MERCURY IN SOIL GAS

Pyramidal tents of transparent plastic were used to funnel soil gas through gold or silver foil to trap mercury. The tents (fig. 1) were constructed of four pieces of 1/8-inch-thick plexiglass, which were 2 feet wide at the base and tapered to 2 inches wide at the top; vertical height of the tent was 22 inches. The tent was formed by joining the plexiglass panels with masking tape. A basket made of 80-mesh stainless-steel wire cloth was placed over the opening in the top and was secured with tape (fig. 2). The tent was then placed on the ground and soil was banked around its base to exclude free movement of air into it from the outside. Gold or silver flakes (about 1 gram) were spread evenly in the wire basket, and a canvas sample sack was taped loosely over the top to prevent the flakes from blowing away (fig. 1). The flakes were 0.007 inch thick and about 1/16 inch square. Under the influence of the sun's rays, the air temperature inside the tent immediately began to rise, setting up convection currents that carried the air in the tent upward through the trap. The tent was left in position for 2 hours, during which time 175 cubic feet of air passed through the trap. In practice, about 10 tents were placed along a traverse within a period of 2 hours and were then collected in order.

Ground Experiments

The recently discovered gold deposit at Cortez, Nev., was chosen for study because rocks in the area contain anomalous concentrations of mercury closely

associated with the gold (Erickson and others, 1966). Much of the area is covered by recent gravels. Measurements of mercury in soil gas were undertaken to determine (1) if measurable amounts of mercury vapor from the gold deposit were migrating through the gravel into the atmosphere and (2) if a significant difference existed between the mercury content in soil gas over barren bedrock and that over gold-bearing bedrock. The results of this study show that greater amounts of mercury in the soil gas are found in the area of known gold mineralization and that the configuration of the mercury anomaly is similar to the configuration of the gold deposit in the bedrock (fig. 3).

Soil samples were also taken at each tent locality and analyzed for mercury. The results (fig. 4) show that the mercury content in the soil does not reflect the known gold deposit as well as does the mercury content in the soil gas. The mercury collected from soil gas during a 2-hour period ranged from 2 ng (nanograms) to 175 ng, with background being about 5 ng. The maximum anomaly-to-background ratio, therefore, was about 35:1. The background mercury content in soil in the area is about 30 ppb (parts per billion) and the highest amount found was 200 ppb; thus the maximum anomaly-to-background ratio is about 7:1.

Although the configurations of the anomalies for mercury in soil gas are different from those in soil, they are sufficiently similar to suggest that the mercury detected in the soil gas may have been derived from the soil. However, the lack of correlation between mercury in soil gas and mercury in soil, as shown in figure 5, indicates that the source of the mercury found in the soil gas is not the surface soil. The conformity of the soil-gas anomaly to known mineralized bedrock suggests that the mercury was derived from bedrock.

In order to further test the possibility that the mercury in soil gas may have been derived from the soil itself, 10 g of soil collected at the tent sites was heated at 60°C for 2 hours and the expelled mercury was collected by amalgamation on gold or silver and measured; the temperature was similar to that actually attained within the tents during the field experiments, and the heating time was the same. The values obtained were plotted against those of mercury in soil gas that was collected at corresponding field sites (fig. 6). The apparent randomness of the plot, as in the experiment previously described, suggests that the soils were not the source of the mercury detected in the soil gas. This conclusion is further substantiated by comparison of the total amount of mercury in the soil and the total amount in the soil gas, as shown in figure 6. A maximum of 6 ng of mercury was released from the soils in a 2-hour period; as much as 175 ng of mercury, however, was trapped from the soil gas in the same period of time.

The relation between the mercury content in several soil-gas samples and the barometric pressure at the time of collection is plotted in figure 7. Although insufficient data have been collected to clearly demonstrate the dependence of mercury in soil gas on change in barometric pressure, the available data suggest that more mercury is detected at lower than at higher pressure.

Daily measurement of barometric pressure with a microbarograph has revealed a consistent diurnal variation in all areas studied. The pressure begins to drop at about 8:00–9:00 a.m. and falls steadily until about 6:00–7:00 p.m.; then it begins to rise steadily through the night. Thus, if no atmospheric disturbances exist, the pressure record transcribes an approximate sine wave with maximum rate of drop about midday. Variation of mercury content in soil gas collected at different times during the day is shown in figure 8. These data show that the maximum amount of mercury is collected about midday, a period corresponding to the maximum rate of fall in barometric pressure.

The effect of the thickness of overburden on soil-gas measurements was investigated in the Cortez area. Thickness of overburden is plotted against mercury content in soil gas in figure 9. The data suggest that more mercury is found in the soil gas over deeper overburden, but additional data are needed to confirm or deny such a correlation. However, variable thicknesses of overburden did not seem to hamper the successful use of mercury in soil gas in outlining mineralized bedrock at Cortez.

The reproducibility of the soil-gas measurements was determined by repeating measurements at eight sites in the Cortez area on different days; the data are plotted in figure 10. With the exception of the measurements at site 1, the pattern obtained was the same each day.

Mercury in the soil gases in several other mining districts was investigated. In the Ivanhoe district north of Battle Mountain, Nev., mercury in soil gas was collected by means of the plastic tents. A tent set up on soil over the projection of a cinnabar-bearing vein collected 600 ng of mercury in 2 hours, whereas a tent set up 50 feet away from the vein collected 100 ng of mercury during the same period. At the Silver Cloud mine in the same district, plastic tents were used to collect mercury in soil gas over disseminated and banded cinnabar occurring in silicified volcanic tuff and ash (opalite). As much as 1,300 ng of mercury was collected in a 2-hour period, whereas only 4–5 ng of mercury was collected in tents in areas away from the opalite. Mercury in soil gas was collected at several sites in the Coeur d'Alene district of Idaho. As much as 60 ng of mercury was found in soil gas collected in a 2-hour period. The highest amounts coincided with known mineralized areas.

APPARATUS AND TECHNIQUE FOR MEASURING MERCURY IN AIR

The ground experiments demonstrated that mercury vapor was released to the atmosphere. The next logical

step was to determine how high into the atmosphere the mercury vapor ascended and if it too reflected bedrock mineralization. If it could be demonstrated that mercury vapor was found in the above-surface air, it might make possible the collection of mercury in air from ground-based vehicles or aircraft and greatly broaden the potential application of this exploration technique.

First, it was necessary to determine if mercury could be found in the air above the ground. Traps were set up above the bedrock surface of cinnabar-bearing opalite at the Silver Cloud mine. The traps were mounted on a pole at heights of 1 foot, 7 feet, and 14 feet. The following data were obtained:

Height above surface (in feet)	Replicate measurements of mercury collected in a 2-hour period (in nanograms)		
	1	2	3
14	--	17	43
7	26	19	60
1	13	12	13

The volume of air passing through the traps was not measured; however, the experiment showed that mercury could be detected at least as much as 14 feet above the surface. The smaller amounts collected as 1 foot above may have been the result of less air passing through the traps because of frictional drag near the surface, and indeed, the greater variability in amounts of mercury found in the higher traps suggests greater variability in the volume of air passing through the traps.

Experiments from Ground-based Vehicles

After demonstrating that mercury vapor was found in air above the ground at the Silver Cloud mine, the next step was to determine if differences in the mercury content in this air reflected known mineralization. Air sampling was done from a moving vehicle along a 40-mile traverse through the Ivanhoe mining district. Air was captured through a 6-inch funnel which was mounted on the front bumper of the vehicle; the air was then brought into the cab through plastic tubing and was passed through gold flakes to trap ther mercury. The traps were changed at 3-mile intervals. The lowest amount obtained was 2 ng and the highest, 19 ng. The highest amounts were collected over the area of known mercury production.

Aircraft Experiments

Because significant quantities of mercury had been found as much as 14 feet above the surface of the ground, additional experiments were carried out to determine (1) the altitude to which mercury ascends in air and (2) the correlation, if any, of mercury in air at higher altitudes with known mineral deposits.

An intake tube was installed in a single-engine Beaver aircraft to bring air inside the cabin, and a measured volume of air was passed through noble-metal foil traps. In order to determine the optimum altitude for mercury collection, air was collected at different altitudes from 100 to 1,000 feet. The data are shown in figure 11. These data show a tapering off of mercury collected above 200 feet, and therefore all subsequent flying in these experiments was done at an altitude of 200 feet.

Mercury in air was measured in Arizona over two mercury deposits and two porphyry copper deposits, and several long traverses were flown along the highway from Quartzsite, Ariz., to the Colorado River at Blythe, Calif., in order to determine the background concentration of mercury in air. The data obtained are summarized in table 1. One mercury deposit was in the Superstition Mountains east of Phoenix; the other, in the Dome Rock Mountains near Quartzsite, where cinnabar occurs in Cambrian schist. Air collected over these two deposits contained 10–20 times more mercury than background air.

Mercury was collected in air over the porphyry copper deposits of the New Cornelia pit at Ajo and the Tiro and Oxide pits at Silver Bell. At Ajo, the fact that the greatest concentration of mercury collected (30 ng per cubic meter) was over the edge of the pit suggests a possible peripheral enrichment of mercury. Higher concentrations of mercury were found in air over the open pits at Silver Bell than at Ajo. At both copper deposits the mercury in air was 5–10 times the mercury in background.

CONCLUSIONS

Mercury in soil gas collected at the surface has delineated part of the known gold deposits at Cortez, Nev., through as much as 100 feet of gravel. Mineralized veins and faults are readily detectable by measurement of mercury in soil gas.

The single experiment in which mercury in air was collected from a moving vehicle showed that the areas of the highest concentrations of mercury coincided with the known mineralized areas in the Ivanhoe district, Nevada.

Table 1.—Summary of data for mercury in air collected by means of aircraft

[Results are in nanograms per cubic meter]

Area	Min	Max	Avg
Superstition Mountains	58	66	62
Dome Rock Mountains	12	57.5	31.4
Ajo	12	30	18.8
Silver Bell	18.5	53.2	27.6
Colorado River at Blythe, Calif., to Quartzsite, Ariz.[1]	1.6	7.2	4.5

[1] Background concentration.

Measurable amounts of mercury were detected in air as high as 1,000 feet above the surface, and the greatest concentrations were found below 300 feet. Higher concentrations of mercury are found in air over base- and precious-metal ore deposits than in air over unmineralized bedrock.

SIGNIFICANCE

Experience in geochemical exploration has shown that dispersion halos, which reflect mineralized rock, are usually limited to bedrock or residual overburden. Consequently, geochemical methods have not been successfully applied in areas of transported or postmineralization overburden. If, however, postmineralization overburden is permeable to the passage of mercury vapor, the measurement of mercury in soil gas or air may be useful in detecting concealed mineral deposits. The nature of the overburden and perhaps even its thickness may be of minor importance. Such a technique might be used to investigate the mineral potential of pediments in the Basin and Range province or of the vast areas of the southwest that are overlain by volcanic rocks or alluvium.

The use of an aircraft to detect mercury may make it possible to explore large and inaccessible areas rapidly. It may be possible to delineate or extend metallogenic provinces by using mercury as an indicator element, or it may be possible to detect new large regional mineral belts or trends, particularly if the data on mercury are used in conjunction with regional geophysical data.

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FIGURES 1–11

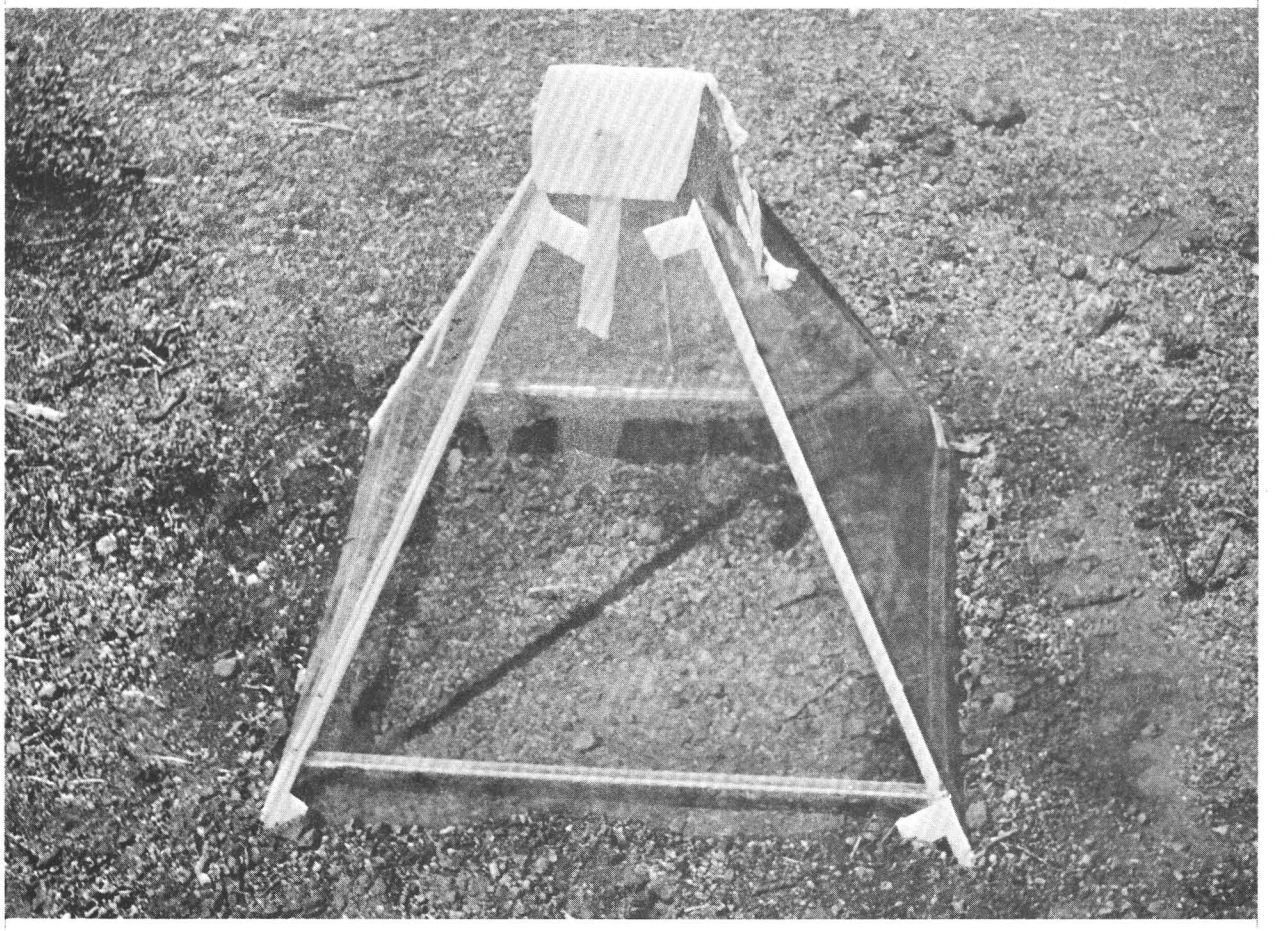

Figure 1.—Photograph of transparent plexiglass tent. Tent is 2 feet wide at base.

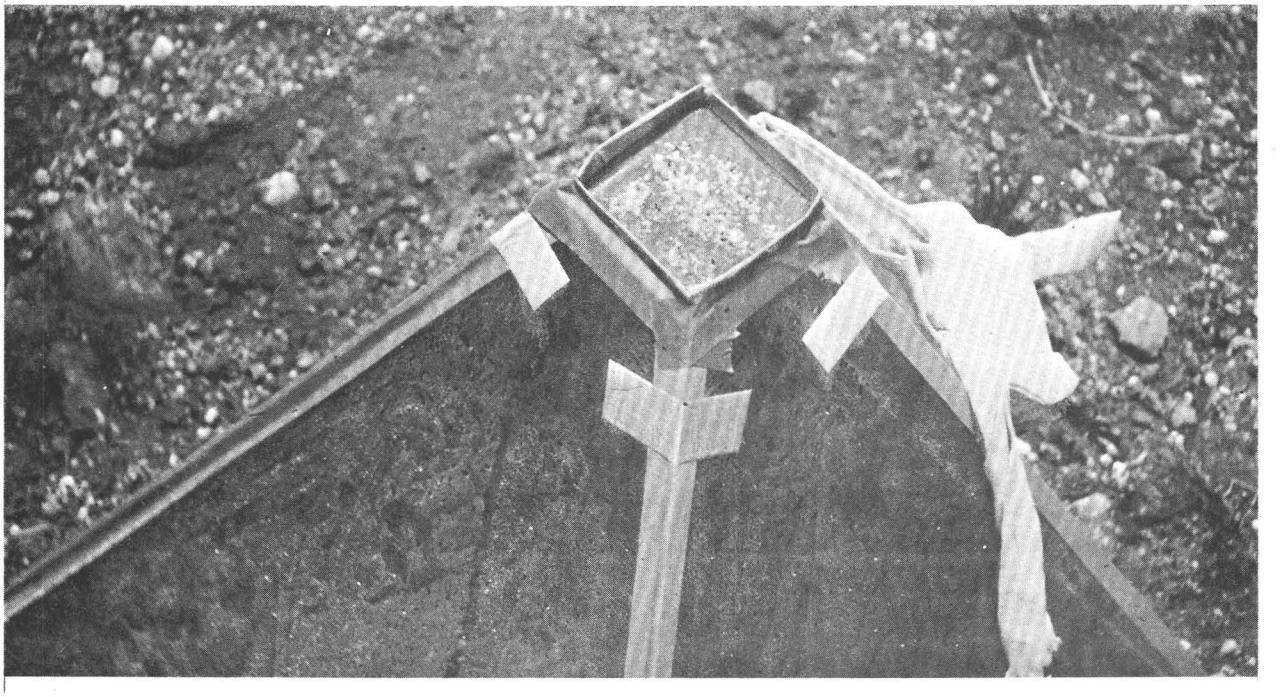

Figure 2.—Photograph of wire basket on top of tent. Basket is 2 inches long on each side.

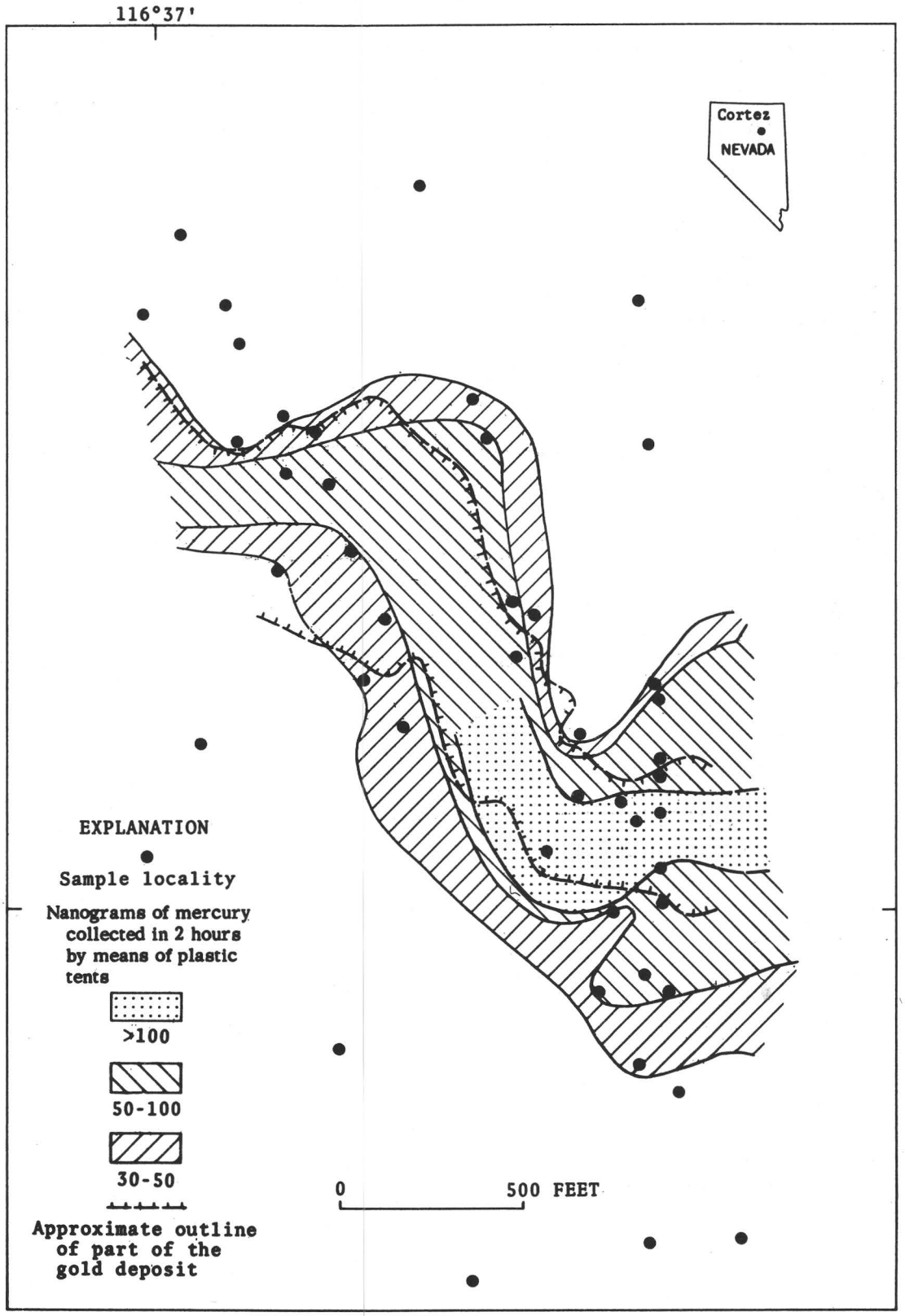

Figure 3.—Mercury content in soil gas at Cortez, Nev.

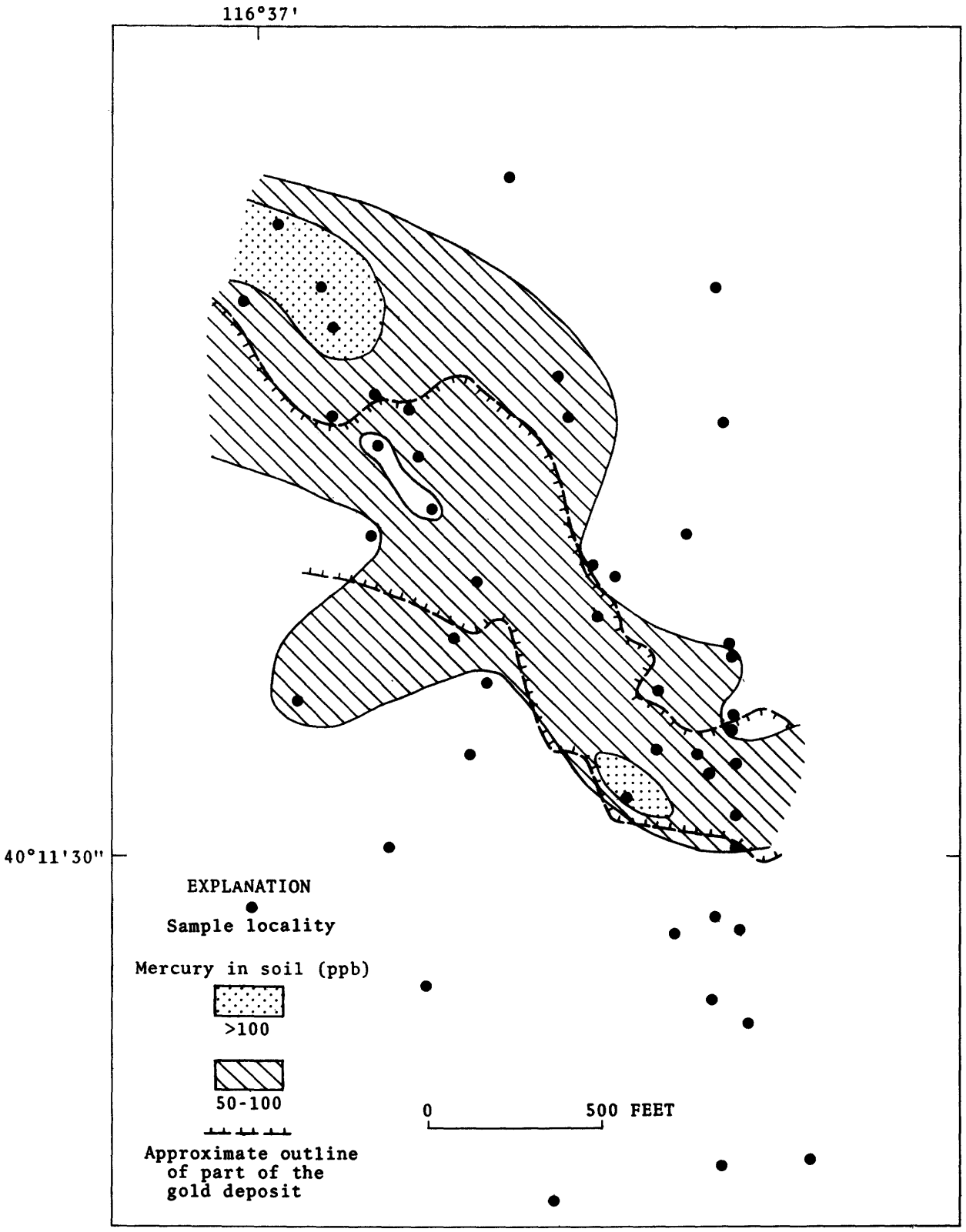

Figure 4.—Mercury content in soil at Cortez, Nev.

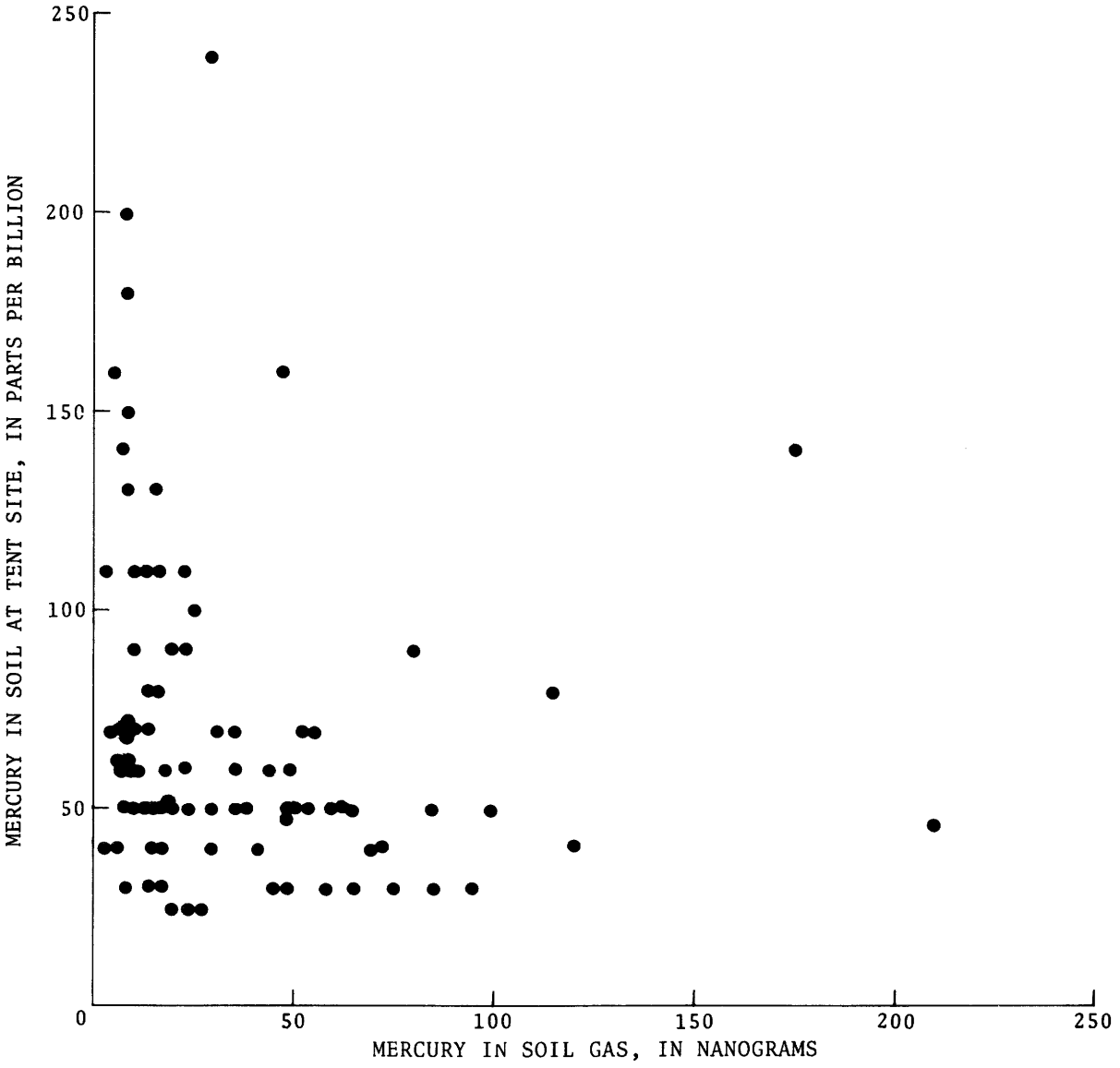

Figure 5.—Scatter diagram showing mercury content in soil gas versus mercury content in soil.

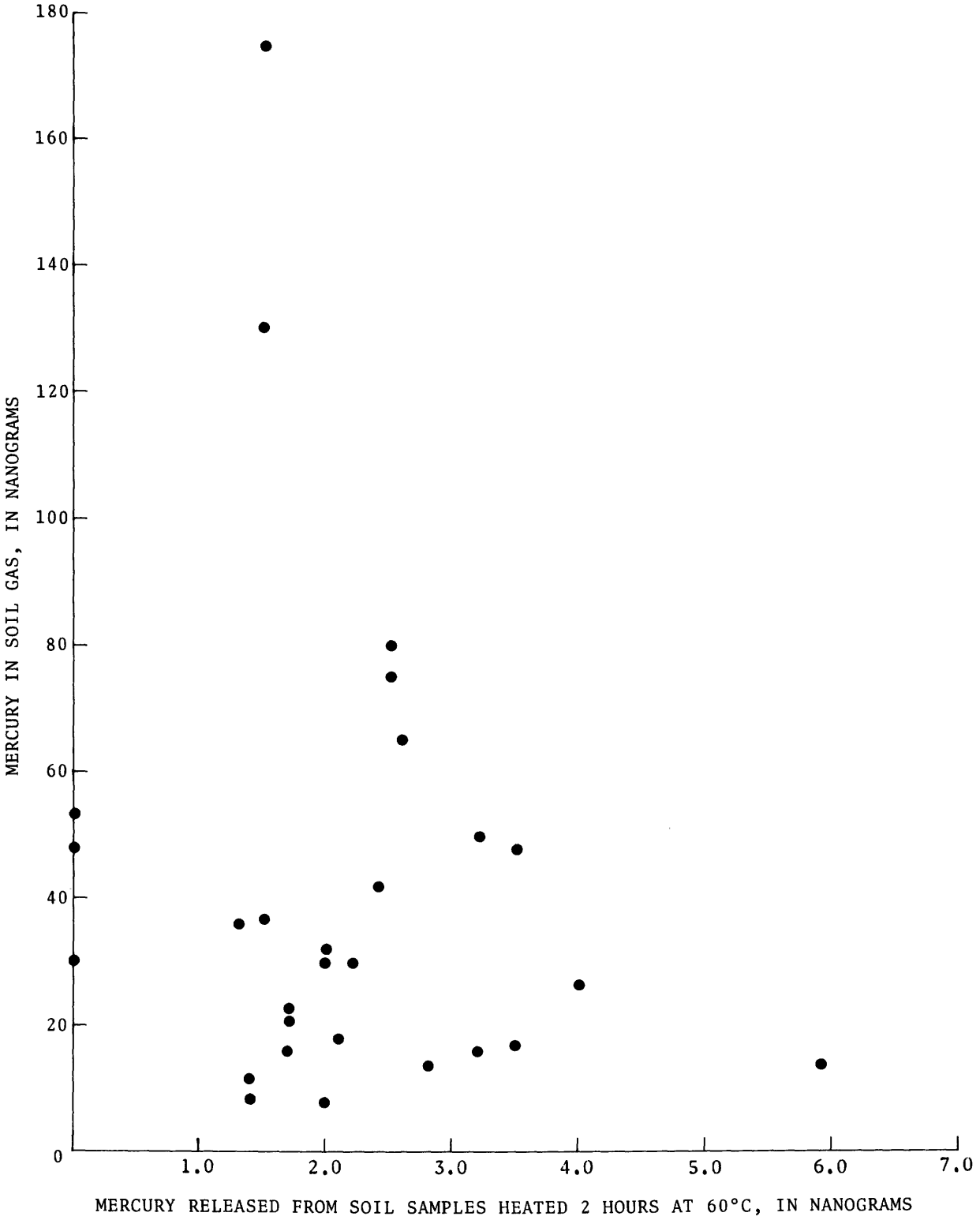

Figure 6.—Scatter diagram showing mercury content in soil gas versus amount of mercury released from soils at 60°C.

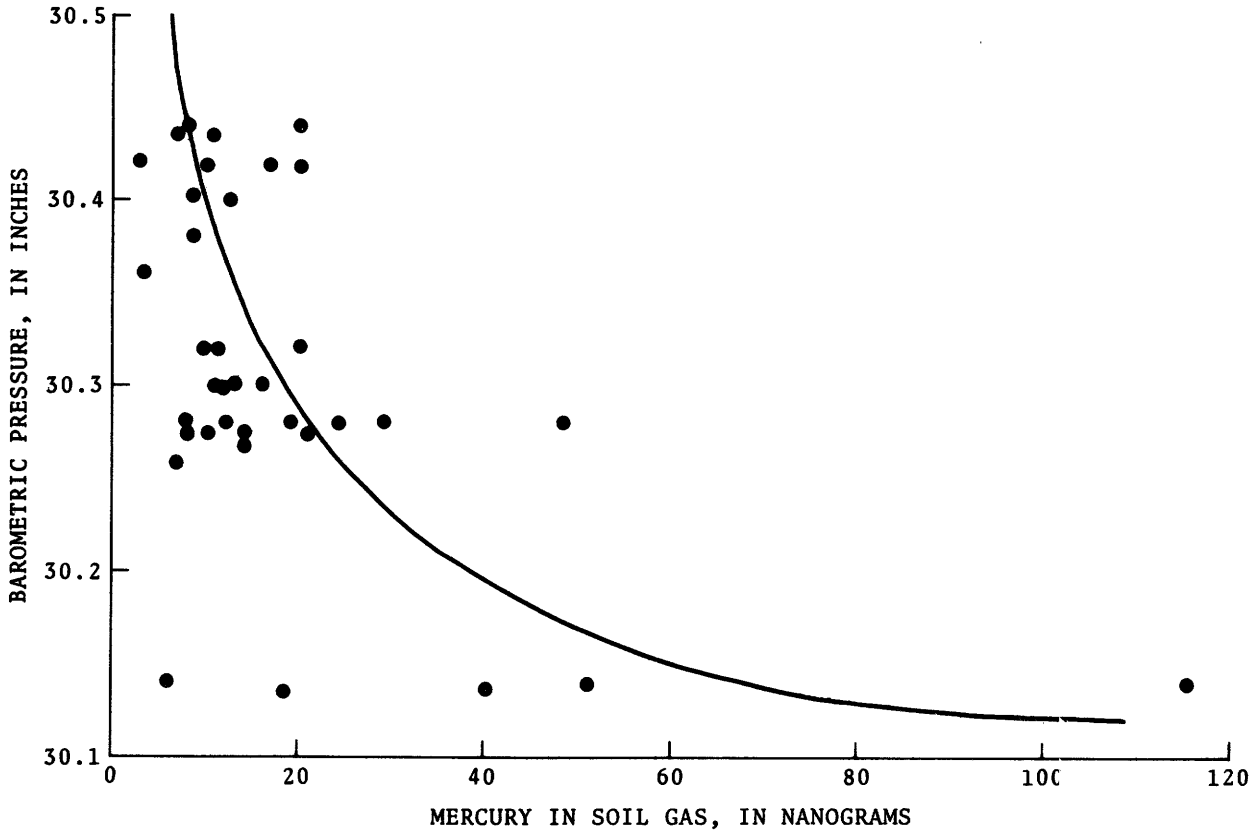

Figure 7.—Relation of barometric pressure to mercury content in soil gas.

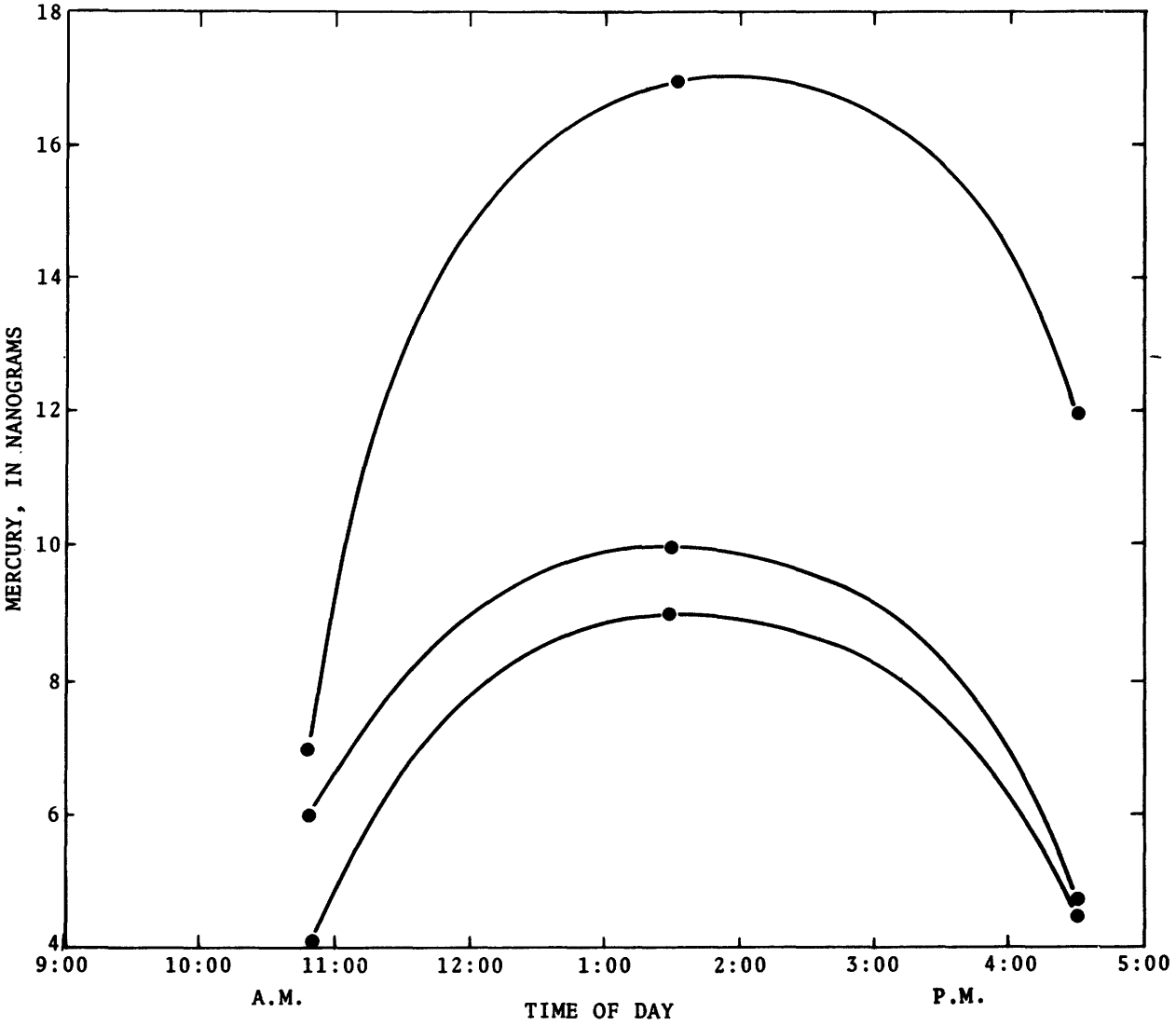

Figure 8.—Variation of mercury content in soil gas with time of collection.

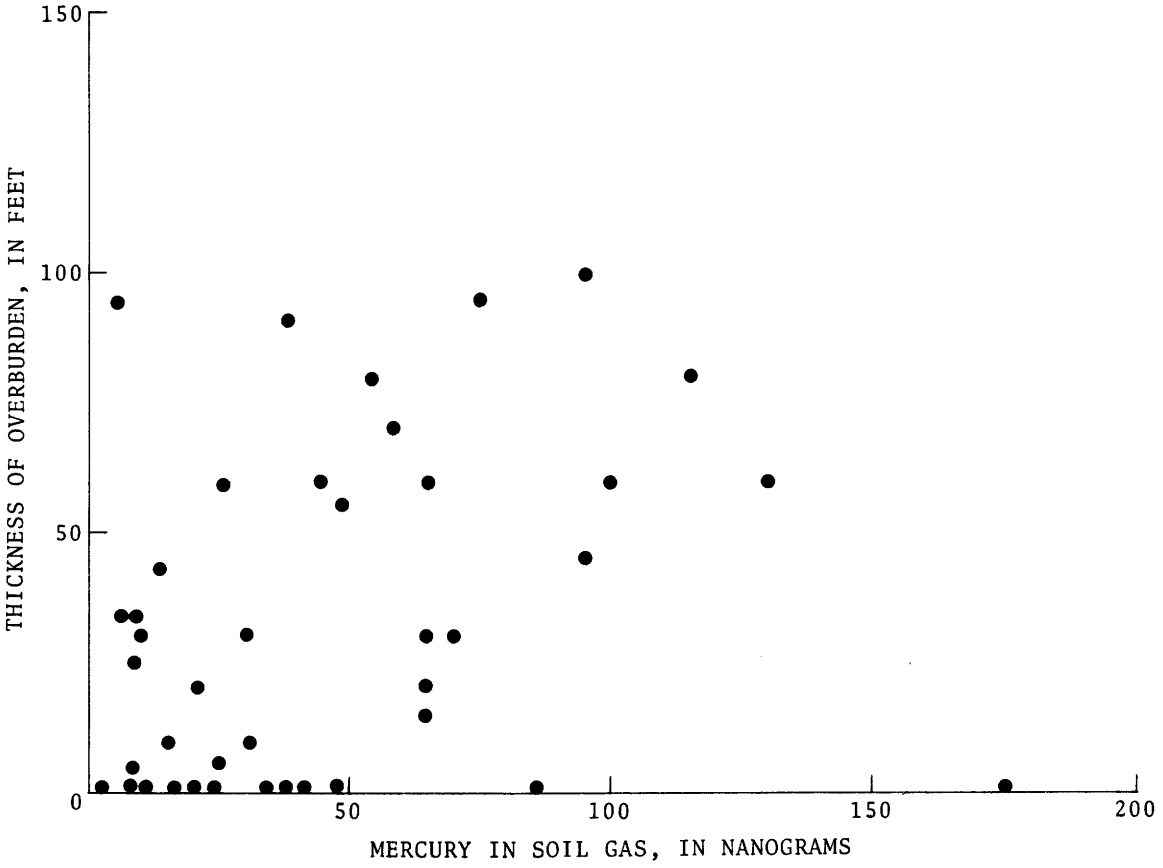

Figure 9.—Relation of thickness of overburden to mercury content in soil gas.

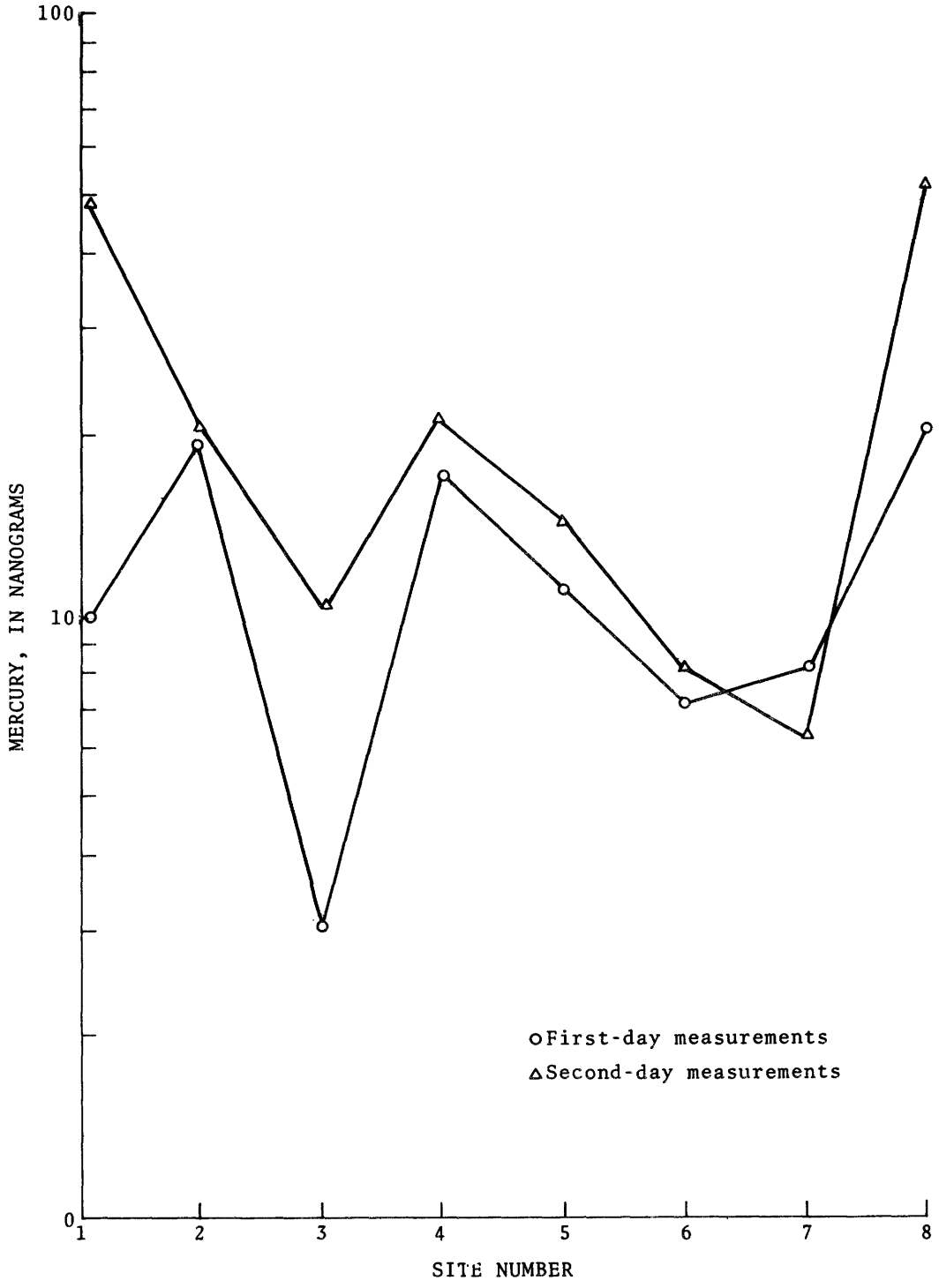

Figure 10.—Reproducibility of measurements of mercury in soil gas.

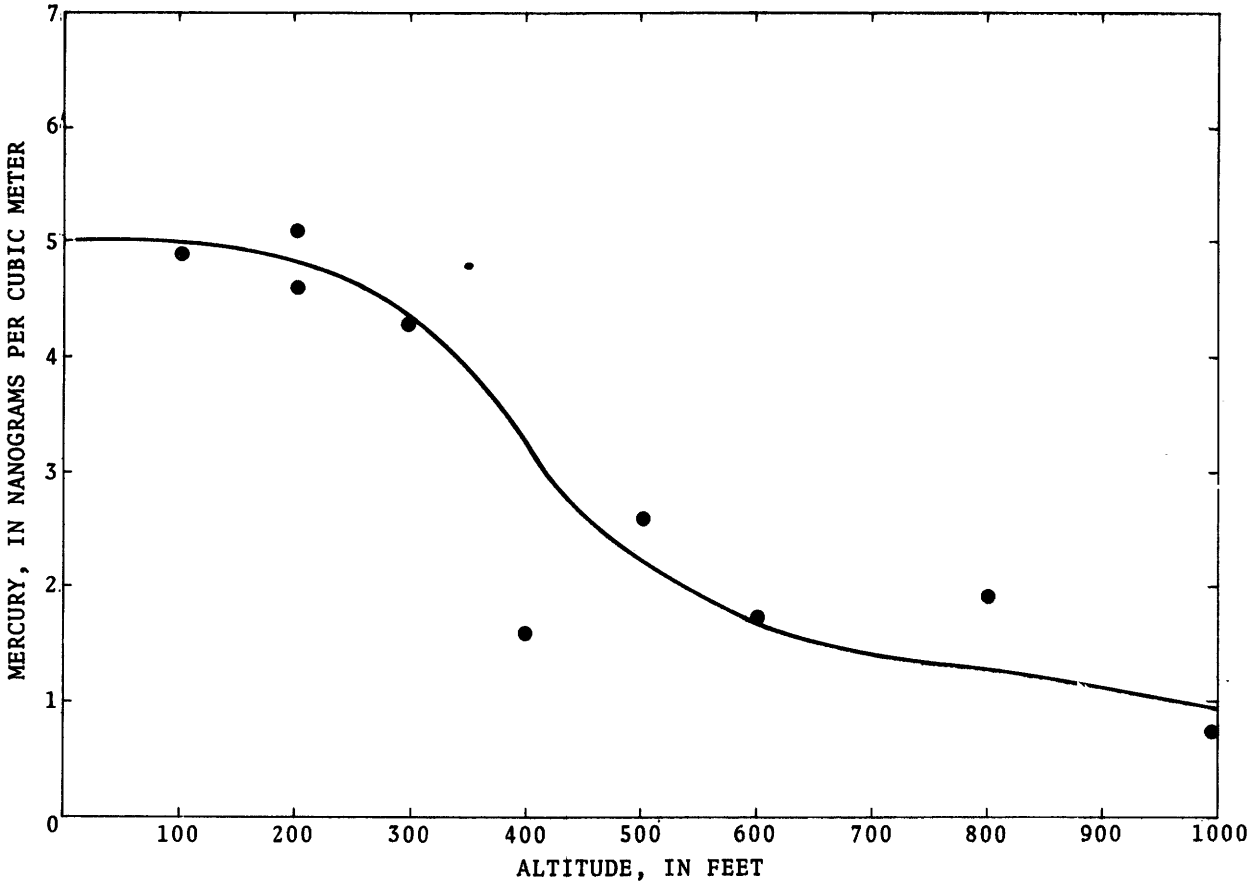

Figure 11.—Mercury in air as a function of altitude.

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